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6 CHAPTER SIX: QUALITY ASSURANCE

Quality Assurance specifications require that the acceptance of material be the responsibility of INDOT. The specification addresses specifically:

1. The units of material quantity used for acceptance.

2. The process of obtaining random samples.

3. What mixture characteristics are considered of critical importance.

4. At what test values can the mixture be accepted at 100% payment.

5. At what levels can the mixture serve at less than design intent and still be of value, and be paid at some adjusted price.

6. At what level should rejection of the material be considered.

7. An appeal procedure for resolving disagreements in QC and QA test results.

This chapter discusses procedures and requirements for sampling, testing, and payment of superstructure concrete.

SUBLOTS AND LOTS

Quality Assurance specifications consider a sublot as typically 40 m^3 as measured against the plan quantity for each mix design of superstructure concrete. A partial sublot of less than 20 m^3 will be considered as part of the previous sublot and a partial sublot of 20 m^3 to 39 m^3 will be considered an individual sublot.

A lot will typically consist of three sublots or 120 m^3 of planned quantity of superstructure concrete for each mix design. If there is only one sublot in an incomplete lot then the sublot will be included in the previous lot. If there are two sublots in an incomplete lot then the quantity of material will be considered a lot. Therefore, a lot may contain two, three or four sublots.

If the superstructure concrete is placed at several locations on one contract, such as one bridge to another bridge or one phase to another phase, then the sublots will be determined in the order that the material was placed.

RANDOM SAMPLING

Sampling of material for acceptance testing is done by INDOT on a random basis using ITM 802. A random cubic meter of superstructure concrete within a sublot is determined and the location on the bridge deck of the random quantity is established. The random locations are not given to the Contractor so that there will be no possible influence on the production operations. If the random quantity falls within a QC/QA item location not on the bridge deck, then the material is sampled during the placement of concrete at that location.

Random Numbers

A table of Random Numbers from ITM 802 (Figure 6.1) is used to determine the random quantity. The numbers occur in this table without aim or reason and are in no particular sequence. Therefore, samples obtained by the use of this table are truly random or chance, and eliminate any bias in obtaining samples.

To use this table to determine the random cubic meter of concrete to sample, select without looking one block in the table. After selecting the block the top left number in the block is the first random number used. This number will be the beginning number for the project. Proceed down the column for additional numbers and proceed to the top of the next column on the right when the bottom of the column is reached. When the bottom of the last column on the right is reached, proceed to the top of the column at the left. If all numbers in the table are used before the project is completed select a new starting number and proceed in the same manner.

Sample Location

The location where the random sample is obtained is determined by first calculating a random quantity and then determining where the random quantity will be placed. The QC/QA superstructure concrete item quantities and locations are detailed in the plans and often include bridge deck and several non-bridge deck items such as wing walls, end bent diaphragms, and pier diaphragms. When the random sample location occurs in one of these non-bridge deck items, the concrete is diverted to the bridge deck during the pouring of the item and the sample obtained from this material.

0.576	0.730	0.430	0.754	0.271	0.870	0.732	0.721	0.998	0.239
0.892	0.948	0.858	0.025	0.935	0.114	0.153	0.508	0.749	0.291
0.669	0.726	0.501	0.402	0.231	0.505	0.009	0.420	0.517	0.858
0.609	0.482	0.809	0.140	0.396	0.025	0.937	0.310	0.253	0.761
0.971	0.824	0.902	0.470	0.997	0.392	0.892	0.957	0.040	0.463
0.053	0.899	0.554	0.627	0.427	0.760	0.470	0.040	0.904	0.993
0.810	0.159	0.225	0.163	0.549	0.405	0.285	0.542	0.231	0.919
0.081	0.277	0.035	0.039	0.860	0.507	0.081	0.538	0.986	0.501
0.982	0.468	0.334	0.921	0.690	0.806	0.879	0.414	0.106	0.031
0.095	0.801	0.576	0.417	0.251	0.884	0.522	0.235	0.389	0.222
0.509	0.025	0.794	0.850	0.917	0.887	0.751	0.608	0.698	0.683
0.371	0.059	0.164	0.838	0.289	0.169	0.569	0.977	0.796	0.996
0.165	0.996	0.356	0.375	0.654	0.979	0.815	0.592	0.348	0.743
0.477	0.535	0.137	0.155	0.767	0.187	0.579	0.787	0.358	0.595
0.788	0.101	0.434	0.638	0.021	0.894	0.324	0.871	0.698	0.539
0.566	0.815	0.622	0.548	0.947	0.169	0.817	0.472	0.864	0.466
0.901	0.342	0.873	0.964	0.942	0.985	0.123	0.086	0.335	0.212
0.470	0.682	0.412	0.064	0.150	0.962	0.925	0.355	0.909	0.019
0.068	0.242	0.777	0.356	0.195	0.313	0.396	0.460	0.740	0.247
0.874	0.420	0.127	0.284	0.448	0.215	0.833	0.652	0.701	0.326
0.897	0.877	0.209	0.862	0.428	0.117	0.100	0.259	0.425	0.284
0.876	0.969	0.109	0.843	0.759	0.239	0.890	0.317	0.428	0.802
0.190	0.696	0.757	0.283	0.777	0.491	0.523	0.665	0.919	0.246
0.341	0.688	0.587	0.908	0.865	0.333	0.928	0.404	0.892	0.696
0.846	0.355	0.831	0.218	0.945	0.364	0.673	0.305	0.195	0.887
0.882	0.227	0.552	0.077	0.454	0.731	0.716	0.265	0.058	0.075
0.464	0.658	0.629	0.269	0.069	0.998	0.917	0.217	0.220	0.659
0.123	0.791	0.503	0.447	0.659	0.463	0.994	0.307	0.631	0.422
0.116	0.120	0.721	0.137	0.263	0.176	0.798	0.879	0.432	0.391
0.836	0.206	0.914	0.574	0.870	0.390	0.104	0.755	0.082	0.939
0.636	0.195	0.614	0.486	0.629	0.663	0.619	0.007	0.296	0.456
0.630	0.673	0.665	0.666	0.399	0.592	0.441	0.649	0.270	0.612
0.804	0.112	0.331	0.606	0.551	0.928	0.830	0.841	0.702	0.183
0.360	0.193	0.181	0.399	0.564	0.772	0.890	0.062	0.919	0.875
0.183	0.651	0.157	0.150	0.800	0.875	0.205	0.446	0.648	0.685

FIGURE 6.1 - RANDOM NUMBERS

The procedure for determining the random sample location is as follows:

1. Determine the sublot quantity to the nearest 0.1 m^3. The quantity may be between 20 m^3 and 59 m^3 depending on whether there is a partial sublot.

2. Determine the quantity of concrete in the bridge deck to the nearest 0.1 m^3. QC/QA superstructure concrete may be placed in locations other than the bridge deck, such as end bent or pier diaphragms or wing walls. The quantity is determined by:

   Bridge Deck Sublot Quantity (m^3) = Sublot Quantity - QC/QA Non-Bridge Deck Quantity

3. Select a random number.

4. Calculate the random sublot quantity to the nearest 0.1 m^3 by:

   Random Quantity = Sublot Quantity x Random No.

   If the random sublot quantity falls within the QC/QA item not placed in the bridge deck, sample the concrete from the point of placement. If the random quantity is placed in the deck, proceed to step #5.

5. Calculate the random sublot distance to the nearest 0.1 m required for the random quantity of the bridge deck concrete in the sublot by:

   $$\text{Random Distance (m)} = \frac{\text{Random Quantity } (m^3) \times 10^6}{\text{Width (mm)} \times \text{Depth (mm)}}$$

   where:
   Width = Bridge Deck Pour Width
   Depth = Average Section Depth of Bridge Deck Concrete including Beam Fillets and Copings

6. Calculate the length of the bridge deck sublot quantity to the nearest 0.1 m for the sublot by:

   $$\text{Length of B.D. Quant. (m)} = \frac{\text{B.D. Quant. } (m^3) \times 10^6}{\text{Width (mm)} \times \text{Depth (mm)}}$$

7. Determine the sublot location to the nearest 0.1 m in relation to the beginning of the lot. The beginning of lot 1 sublot 1 would be considered 0. The end of sublot 1 should be 0 plus the length of bridge deck sublot quantity calculated in step #6. Each subsequent sublot would begin with the end of the previous sublot and end with the sublot beginning distance plus the length of bridge deck sublot quantity calculated for that sublot.

8. Calculate the distance from the beginning of the lot to the random sample location by:

Random Distance from Beginning of Lot = Random Sublot Distance + Beginning of Sublot Distance

If the random sublot distance from the beginning of the lot falls within the limits of the end bent or pier diaphragm, the sample will be obtained from the point of placement. The distance to the random sample location is measured from the beginning of the QC/QA superstructure material on the bridge deck and along the centerline of the bridge deck pour. Distances from the beginning of the QC/QA superstructure material, such as each 2 m, should be marked on the bridge deck forms to aid in determining the random location.

Example (Figure 6.2):

Lot No. 1

Distance from Beginning of Lot to Pier No. 2	= 32.0 m
Width of Pier No. 2 Diaphragm	= 1.4 m
Width of Bridge Deck Pour	= 12100 mm
Average Depth of Bridge Deck	= 203 mm

Lot No. 1, Sublot No. 1

Sublot Size	= 40 m^3
Bent No. 1 Diaphragm Quantity	= 7.0 m^3
Random Number	= 0.509
Bridge Deck Quantity	= 40 - 7.0
	= 33.0 m^3
Random Quantity in Sublot 1	= 40 x 0.509
	= 20.4 m^3

(Sample Location Occurs in Bridge Deck Since 20.4 > 7.0)

$$\text{Random Distance in Sublot 1} = \frac{(20.4 - 7.0) \times 10^6}{12100 \times 203}$$

$$= 5.5 \text{ m}$$

Length of Bridge Deck Quantity $= \frac{33.0 \times 10^6}{12100 \times 203}$
$= 13.4$ m

Beginning Sublot Location = 0
Ending Sublot Location = 0 + 13.4
(Distance from Beginning of Lot) = 13.4 m

Random Distance from Beginning of Lot = 5.5 + 0
(Sample Location) = 5.5 m

Lot No. 1, Sublot No. 2

Sublot Size = 40 m^3
Random Number = 0.371

Length of Bridge Deck Quantity $= \frac{40 \times 10^6}{12100 \times 203}$
$= 16.3$ m
Location of End of Sublot = 13.6 + 16.3
(Distance from Beginning of Lot) = 29.7 m
Sublot Distance will not reach Pier No. 2 Diaphragm

Random Quantity in Sublot 2 = 40 x 0.371
= 14.8 m^3

Random Distance in Sublot 2 $= \frac{14.8 \times 10^6}{12100 \times 203}$
$= 6.0$ m

Beginning Sublot Location = 13.4 m
(End of Sublot 1)

Ending Sublot Location = 13.4 + 16.3
(Distance from Beginning of Lot) = 29.7 m

Random Distance from Beginning of Lot = 6.1 + 13.4
(Sample Location) = 19.5 m

Lot No. 1, Sublot No. 3

Sublot Size = 40 m^3
Pier No. 2 Diaphragm Quantity = 8.6 m^3
Random Number = 0.165

Bridge Deck Quantity = 40 - 8.6
= 31.4 m^3
Random Quantity in Sublot 3 = 40 x 0.165
= 6.6 m^3

INDIANA DEPARTMENT OF TRANSPORTATION
MATERIALS AND TESTS DIVISION

RANDOM SAMPLING FOR SUPERSTRUCTURE CONCRETE

Contract No. R-24500 Lot No. 1

Diaphragm Locations 32.0 TO 33.4 m from Beginning of Lot

Sublot No.	Sublot Size (m3)	QC/QA Non-Bridge Deck Quant. (m^3)	Bridge Deck Quant. (m^3)	Random No.	Random Quant. (m^3)	Bridge Deck Pour Width (mm)	Depth of Bridge Deck (mm)	Random Distance (m)	Length of Bridge Deck Quant. (m)	Sublot Location		Random Distance from Beginning of Lot (m)
										Beginning (m)	Ending (m)	
	A	B	A-B=C	D	AxD=E	F	G	$\frac{Ex10^6}{F \times G} = H$	$\frac{Cx10^6}{F \times G} = I$	J	I + J	H + J
1	40	7.0	33.0	0.509	20.4	12100	203	5.5*	13.4	0	13.4	5.5
2	40	0	40	0.371	14.8	12100	203	6.0	16.3	13.4	29.7	19.4
3	40	8.6	31.4	0.165	6.6	12100	203	2.7	12.8	29.7	42.5	32.4
4												

Remarks * E = 20.4 - 7.0 = 13.4

Signed _____

FIGURE 6.2

Random Distance in Sublot 3 $= \frac{6.6 \times 10^6}{12100 \times 203}$

$= 2.7$ m

Length of Bridge Deck Quantity $= \frac{31.4 \times 10^6}{12100 \times 203}$

$= 12.8$ m

Beginning Sublot Location (End of Sublot 2) = 29.7 m

Ending Sublot Location (Distance from Beginning of Lot) = 29.7 + 12.8 = 42.5 m

Random Distance from Beginning of Lot = 2.7 + 29.7 = 32.4

(Sample location falls within Pier No. 2 Diaphragm location. Sample is therefore obtained from the point of placement)

Sampling Procedure

The Contractor is required to provide an easily assessable means of obtaining concrete samples from the point of placement, and for transporting samples off the bridge deck for testing. Sampling for acceptance will be done by INDOT in accordance with AASHTO T 141.

ACCEPTANCE TESTING

The Contractor is required to submit a mix design and provide verification of the design by a Trial Batch Demonstration. The superstructure concrete properties shall meet the concrete parameters of the specifications prior to placement.

Acceptance testing results are shared with the Contractor. The air content, plastic unit weight, and compressive strength tests are measured for each sublot during concrete operations. The slump of the concrete is visually estimated.

Air Content and Unit Weight

The frequency of tests for the air content and unit weight is one series for each sample for each sublot. The air content will be determined in accordance with AASHTO T 152 when stone or gravel coarse aggregate is used in the concrete and AASHTO T 196 when slag coarse aggregate is used. The concrete material used to obtain the unit weight may be used to conduct the air content test.

A line parallel to the CMD Linear Equation will be established to represent a threshold limit where the water/cementitious ratio becomes 0.420. An individual sublot having a unit weight, for the air content measured, at or below the value representing the maximum allowable water/cementitious ratio, will have two additional cylinders cast. A test specimen will be extracted from each cylinder and tested by INDOT for resistance to chloride ion penetration in accordance with AASHTO T 277 at an age of 60 days. The test value will be the average of the two specimens.

Compressive Strength

The frequency of tests for the compressive strength will be one set of two cylinders for each sublot. The two cylinders will be tested at 28 days in accordance with AASHTO T 22 and the test values averaged to determine the sublot compressive strength.

The Contractor is required to provide sufficient saturated limewater filled containers at the work site for initial curing of compressive strength specimens. The cylinders are completely submerged in the saturated limewater at a temperature of 16 to 27°C for no less than 16 nor more than 48 hours. After the initial curing the cylinders are transported to the laboratory within 4 hours for additional curing, capping, and testing.

Slump

The slump of the concrete is visually estimated during production. If it is suspected that the slump is not within the allowable limits at the point of placement, the Contractor will be informed. The truck in question shall discontinue placement in the structure until a slump test is conducted to verify compliance. If the slump is outside compliance, the Contractor shall test the concrete for air content and unit weight. The truck shall not continue placement in the structure until quality control test results substantiate compliance.

ADJUSTMENT POINTS

Adjustment points are assessed for air content, compressive strength at 28 days, and the range of air content. The range of air content is defined as the difference between the highest test value and the lowest test value for air content within a lot.

Test values for each sublot are entered on the Superstructure Concrete Analysis for Quality Assurance form and averaged for the lot. Unit weight and the resistance to chloride ion penetration test values, if applicable, are also entered on this form. The averages for the lot are compared to the acceptance tolerances designated in the specifications for each property. If the tolerances are not met, adjustment points are

assigned for each property in accordance with the specifications. An example of this procedure is shown in Figure 6.3.

The Superstructure Concrete Analysis for Quality Assurance form is completed by the Project Engineer/Supervisor and sent to the Contractor. Appeals, if necessary, are required to be submitted by the Contractor within five calendar days of receipt of this completed and signed form.

QUALITY ASSURANCE ADJUSTMENT

The adjustment points based on air content, range of air content, and compressive strength at 28 days are used to calculate an adjusted amount of QC/QA superstructure concrete payment for each individual lot. The adjustment for each property is calculated as follows:

$$q_{ai} = L_i \times 125 \times P_{ai}/100$$
$$q_{ri} = L_i \times 125 \times P_{ri}/100$$
$$q_{ci} = L_i \times 125 \times P_{ci}/100$$

where:

q_{ai} = quality assurance adjustment, air content in individual (i^{th}) lot
q_{ri} = quality assurance adjustment, air content range in i^{th} lot
q_{ci} = quality assurance adjustment, compressive strength in i^{th} lot
125 = unit price for material, $\$/m^3$
P_{ai} = adjustment points for air content in i^{th} lot
P_{ri} = adjustment points for air content range in i^{th} lot
P_{ci} = adjustment points for compressive strength in i^{th} lot

The total quality assurance adjustment will be calculated as follows:

$$Q = \Sigma (q_{ai} + q_{ri} + q_{ci})$$

For lots i=1 to n

where:

Q = total quality assurance adjustment
i = individual lot
n = last lot

An example of this procedure is shown in Figure 6.3

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INDIANA DEPARTMENT OF TRANSPORTATION
MATERIALS AND TESTS DIVISION

SUPERSTRUCTURE CONCRETE ANALYSIS FOR QUALITY ASSURANCE

CONTRACT NO. _____ MIXTURE: w/o Silica Fume w/Silica Fume LOT NO. _____

Threshold Equation for CMD at Max. Allowable W/C: UW = -24.6 (Air) + 2391

ADJUSTMENT POINTS							
Date	9/26/01	9/26/01	9/26/01				
Sublot Quantity (m^3)	40	40	40				
	Sublot 1	Sublot 2	Sublot 3	Sublot 4			
Properties					Average	Tolerance Range	Adjustment Points P
Air Content (%)	5.8	4.4	4.2		4.8	4.7-4.9	10
Threshold Unit Weight (kg/m^3)	2248	2283	2288				
Measured Unit Weight (kg/m^3)	2250	2292	2302				
Rapid CI Permeability (Coulombs)	-NA-	-NA-	-NA-				
28 Day Compressive Strength (MPa)	30.54	33.55	36.74		33.61	33.50-33.74	4
Range of Air Content	5.8 - 4.2 = 1.6					0.0-2.9	0

Note: Insert asterisk (*) next to any failing Sublot Acceptance Sample result and submit copy of form to DMTE for processing as Failed Material.

QUALITY ASSURANCE ADJUSTMENT							
Lot Quantity L (m^3)	Adjustment Points			q_a	q_c	q_r	Q
	Air Content Pa	Comp. Strength Pc	Air Content Range Pr	Lx 125x Pa/100 ($)	Lx 125x Pc/100 ($)	Lx 125x Pr/100 ($)	$q_a+q_c+q_r$ ($)
120	10	4	0	1500	600	0	2100

_____ _____
Project Engineer/ Project Supervisor Date

FIGURE 6.3

APPEALS

If the Contractor does not agree with the acceptance test results for a lot of QC/QA superstructure concrete, an appeal may be submitted. The appeal shall satisfy the following criteria:

1. Appeals shall be submitted in writing to the Engineer within five calendar days of receipt of INDOT's written results for the lot.

2. The submission shall contain quality control test data that equals or exceeds the number of tests required.

3. The difference between the acceptance test result and the nearest quality control test result shall be at least 0.5 percent for air content.

4. The difference between the acceptance test result and the nearest quality control test result shall be at least 0.70 Mpa for compressive strength at 28-days.

Cores shall be obtained by the Contractor at the location that most closely approximates the appropriate sublot acceptance sample location. Cores shall be 100 mm in diameter and the Contractor shall fill all core holes with concrete within 24 hours of drilling. If there is an obvious erroneous acceptance test result, INDOT will obtain the cores.

Air Content Appeal for Lot

For an air content appeal for a lot, two cores shall be taken from each sublot that qualifies and averaged. The hardened concrete air content will be determined in accordance with ITM 401 and converted to a value representing the air content in the plastic state.

The average value will be considered as the air content for the sublot in question. This value will be used to determine all subsequent actions involving the sublot and lot.

Compressive Strength Appeal for Lot

For a 28-day compressive strength appeal for a lot, two cores shall be taken from each sublot that qualifies. Each core will be tested for compressive strength in accordance with AASHTO T 24. The two test values will be averaged for the sublot compressive strength value and this value will be used to determine all subsequent actions involving the sublot and lot.

FAILED MATERIALS

Sublot and lot values that are excessively out of tolerance are required to be submitted to INDOT for final adjudication. The test values and adjustment point criteria that will require such submittal include:

1. An individual sublot having an air content test value of less than 4.0 percent or more than 10.0 percent.

2. A resistance to chloride ion penetration test value greater than 4000 coulombs when this test is required for unit weight measures less than the threshold limit.

3. An individual sublot having a 28-day compressive strength test value less than 36.0 Mpa and 30.5 Mpa for concrete with and without silica fume, respectively.

4. A lot having an air content test value average of 4.2 or less and 4.4 and less for concrete with and without silica fume, respectively

   A lot having an air content test value average of 10.0 or greater for concrete with or without silica fume.

5. A lot having a 28-day compressive strength test value average of 32.24 or less and 37.74 or less for concrete with and without silica fume, respectively.

6. A lot having an air content range of 4.1 or greater.

7. A lot having a total of more than 200 adjustment points for air content and 28-day compressive strength ($P_{ai} + P_{ci}$).

As a minimum the Failed Materials Committee will consider the above-noted items for no additional payment adjustment, an increased payment adjustment to offset potential maintenance costs, additional payment to cover the cost of the investigation, no payment, or removal and replacement.